Comparing Cementing Techniques in Total Knee Arthroplasty
Wetzels, Thomas; van Erp, Joost; Brouwer, Reinoud W; Bulstra, Sjoerd K; van Raay, Jos J A M

Published in:
The journal of knee surgery

DOI:
10.1055/s-0038-1669917

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2019

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Comparing Cementing Techniques in Total Knee Arthroplasty: An In Vitro Study

Thomas Wetzels, MD¹,² Joost van Erp, MSc¹ Reinoud W. Brouwer, MD, PhD¹
Sjoerd K. Bulstra, MD, PhD² Jos J. A. M. van Raay, MD, PhD¹

¹ Department of Orthopedic Surgery, Martini Ziekenhuis, Groningen, The Netherlands
² Department of Orthopaedics, Universitair Medisch Centrum Groningen, Groningen, The Netherlands

Address for correspondence Thomas Wetzels, MD, Department of Orthopedic Surgery, Martini Ziekenhuis, Van Swietenplein 1, Groningen 9700 RM, The Netherlands (e-mail: tjmwetzels@gmail.com).

Abstract

Aseptic loosening remains to be a major reason for revision in total knee arthroplasty. Cement penetration of 2 to 5 mm increases the interface strength and consequently decreases the likelihood of loosening. But despite this overall accepted optimal cement penetration, there is still a wide variety of cementing techniques used in total knee arthroplasty. The purpose of this study was to evaluate two cementing techniques on the tibial and femoral sides, with regard to cement penetration. Five paired cadaveric knees were used. A total knee arthroplasty was placed according to standard practice, with a setup that mimics the clinical practice. On the tibial side, we compared the application of cement to the bone surface alone, to the application of cement to both the bone surface and the component. On the femoral side, we compared the application of cement to the posterior condyles of the component and to the anterior and distal parts of the bone surface, to the application of cement to the component alone. After the cement had cured, the arthroplasty was removed and the bone was examined to determine the cement penetration using digital software. When applying cement to both the tibial bone surface and the tibial component, the cement penetration increased compared with applying cement to the tibial bone surface alone (3.46 vs. 2.66 mm, p = 0.007). With regard to the distal femoral cuts, the cement penetration did not vary when applied to either the bone or the component (2.81 vs. 2.91 mm). But applying it to the anterior bone surface did seem preferable, when compared with only applying it to the component. The average cement penetration did not differ, but applying the cement to the bone did enlarge the total length of the cement distribution (2.48 vs. 0.96 mm, p = 0.011). Almost no cement was detected on the posterior surface of the femoral cut. We concluded that applying cement to both the tibial bone surface and the component improves cement penetration.

Keywords
► total knee arthroplasty
► cement
► fixation
► cement penetration
► cementing techniques

Aseptic loosening is still a major concern in total knee arthroplasty. After infection, aseptic loosening is the second most common reason for revision. In fact, it is the most common reason of late revisions (>2 years postoperatively).¹² Aseptic loosening has a complex and multifactorial etiology, but is unlikely to occur in the absence of micromotion.³ In a post-mortem retrieval study of cemented tibial components, greater cement–bone interdigitation resulted in less micromotion.⁴ Other in vitro studies have also shown that the strength of the bone–cement interface increases with greater penetration of cement in the bone surface.⁵–⁸ To acquire a sufficiently stable bone–cement interface, a minimum of 2 to 3 mm of penetration is advocated.⁵,⁸,⁹ However, penetration more than 5 mm should be avoided to decrease the risk of bone necrosis.¹⁰–¹⁴

received January 17, 2018
accepted after revision July 27, 2018

Copyright © by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.
Tel: +1(212) 584-4662.
ISSN 1538-8506.
Many different techniques have been used to improve cement penetration. The penetration of polymethylmethacrylate (PMMA) bone–cement in cancellous bone was improved with the use of pulse lavage,\(^\text{15–17}\) bone suction,\(^\text{16,18}\) and cement gun pressurizing.\(^\text{19,20}\) Despite these encouraging results, not all techniques are commonly used and there is a wide variation in cementing techniques in total knee replacements.\(^\text{21}\)

In two previous studies using sawbones, the cement penetration of various cement techniques was examined.\(^\text{22,23}\) In the trial by Vanlommel et al,\(^\text{22}\) they found an optimal penetration when applying cement to the bone surface of the tibia and the component. But finger packing of the bone surface alone was not examined and is a commonly used technique in our hospital. In the study by Vaninbroukx et al,\(^\text{23}\) they found the best results for cement penetration on the femoral side when applying cement to the anterior and distal bone surface in association with cement on the posterior condyles of the component. Inferior results were found when applying cement to the femoral component alone, although this is again a commonly used technique in our hospital.

Therefore, the aim of this study was to compare the two commonly used cementing techniques used in our hospital, with regard to cement penetration. And compare them to the techniques with the best results as described by these previous studies.\(^\text{22,23}\)

**Materials and Methods**

Five human cadavers were used. They were fresh frozen and stored at \(-20°C\). The cadavers were taken out of storage 2 days before use. The average age was 82.6 years (range: 76–93). There were two male and three female cadavers, all of them were Caucasian. The average body mass index was 26.1 kg/m\(^2\) (range: 18.0–32.9). None of the donors had a medical history of prior surgery to the knees, which was confirmed before the start of our experiment by the absence of scars.

The setup of our experiment resembled the situation in our operating room. The cadavers were cut above the diaphragm and placed on a dissection table. A standard medial parapatellar arthroscopy was used, and the Genesis II CR (Smith & Nephew, London, UK) total knee arthroplasty was inserted according to the manufacturer’s guidelines.

After the bone cuts were made, the surfaces were cleaned thoroughly with pulse lavage and afterward dried with gauzes. The PMMA bone cement (Palacos R + G, Zimmer, Heraeus Kulzer GmbH, Hanau, Germany) was mixed using a vacuum-mixing device (Biomet Optivac) according to the standard protocol. Both tibia and femur were cemented in one stage, starting with the tibia 2 minutes after mixing had started. The knees were placed in full extension directly after the implantation of the components. To account for the lower body temperature, we waited a minimum of 20 minutes for the cement to cure. After which both components were removed, which was facilitated by the application of a layer of Vaseline and aluminum foil on both the tibial and femoral components, similar to the technique described by two previous studies.\(^\text{22,23}\)

After the components had been removed, the distal femur and proximal tibia were excised and cut in two places in a sagittal plane using a band saw at low speed. The femur was cut through the middle of the medial and lateral condyles. The tibia was cut at the middle of the medial and lateral plateau (Fig. 1). These cross-sections were then analyzed to determine the cement penetration.

The same author (T.W.) performed each procedure. For both the tibia and the femur, two different cementing techniques were used. To minimize the influence of different bone density, both techniques were used in the same cadaver. Technique 1 was used on the right leg and technique 2 on the left leg.

**Cementing Techniques Tibia**

Technique 1 consisted of applying cement only to the bone surface using finger packing. In technique 2, cement was applied to the bone surface and the tibial component. A thin layer of cement was first applied to the bone surface by finger packing and then to the tibial component directly from the cement gun (Fig. 2).

**Fig. 1** Top view of tibia plateau with sagittal saw cuts made after the removal of the implant.

**Fig. 2** Cementing techniques of the tibia. (1) Tibia surface and (2) tibial component. The gray area shows the application of cement.
Cementing Techniques Femur

Technique 1 consisted of applying cement to the component alone. Technique 2 consisted of applying cement to the posterior condyles of the component and to the anterior and distal parts of the bone surface (Fig. 3).

Graphical Analysis

To analyze the cement penetration, digital photographs (72 dpi) were made of each cross-section using a Canon EOS 30D camera and a 100-mm macro lens on a tripod on a standardized setup (Fig. 4). A measuring staff to correct for any magnification error accompanied every cross-section. Adobe Photoshop (version 13.0.1) was used to analyze the images.

To exclude the irregularities around the tibial fin, two standardized areas (one anterior and one posterior of the fin) of 600 × 600 pixels (averaging 1.5 × 1.5 cm) were measured. Using the “Magic Wand tool,” the area with cement was selected and measured (Fig. 5). To acquire the average penetration depth, the measured total area was divided by the total length. If there were areas without cement, the separate areas were measured and added to achieve the total area and length.

The femur was analyzed in a similar manner, again using the “Magic Wand tool.” We made a distinction between the anterior, distal (including anterior and posterior chamfer cuts), and posterior surfaces (Fig. 6). The distal, anterior, and posterior surfaces were again analyzed for average cement penetration, as described by the method earlier. Due to the fact that in both techniques the cement was applied on the posterior condyles of the femoral implant, we did not compare these results.

Statistical Analysis

A paired t-test was performed using IBM SPSS Statistics (version 23) for Windows for the statistical comparison. A p-value <0.05 was used as the level of statistical significance.

Results

Tibia

One tibial specimen (of technique 2) was excluded from analysis because the cement layer was damaged during extraction of the tibial component, leaving eight paired knees for the statistical analysis.

The average cement penetration was 2.66 mm (standard deviation [SD] 0.24) for technique 1 and 3.46 mm (SD 0.46) for technique 2, a statistically significant difference (p = 0.007) (Fig. 7).

Femur

There was no difference in average cement penetration of the distal saw cuts between techniques 1 and 2, respectively, 2.91 mm (SD 0.38) versus 2.81 mm (SD 0.38), p = NS (Fig. 8).

Fig. 5 Example of a measurement of the tibia. Standardized area of 600 × 600 pixels is marked by the white solid line. The measured area is marked by the white dotted line.

Fig. 6 Example of a cross-section of the femur.
Also, no difference was found in average penetration of the anterior surfaces. There was however a difference in the length of cement distribution along the anterior surface between techniques 1 and 2 (0.96 vs. 2.48 mm, \( p = 0.011 \)).

In 14 of the 20 posterior condyles (medial and lateral of each cadaver), no cement was found. Of the remaining six, only one had a sufficient average penetration of approximately 3 mm.

Discussion

Increased cement penetration creates a more stable arthroplasty, and theoretically should lead to a decreased incidence of aseptic loosening.\(^4\)\(^-\)\(^8\) Previous studies have investigated various techniques to improve the cement penetration.\(^15\)\(^-\)\(^20\)

For both the tibia and femur, we compared two cementing techniques with regard to penetration. We aimed to do this in a way, which resembles the common practice in our operating room, with techniques such as pulse lavage and vacuum cement mixing.

The small number of cadavers used is a limitation of our study, but is comparable to previous studies.\(^22\)\(^,\)\(^23\) We were also not informed about the bone mineral density of each individual cadaver, which can influence the cement penetration. We tried to minimize the influence by comparing the two techniques in each individual cadaver. The body temperature of our cadavers was lower than normal body temperature, and this could have an effect on the normal behavior of the cement. Finally, when analyzing the cement area, we did not take in account any possible discrepancies of the bone surfaces, which may lead to overestimation of the cement penetration.

Despite these limitations, we believe that our results are relevant due to the fact that they are comparable to the values found in the previous studies using sawbones.\(^22\)\(^,\)\(^23\) The average penetration of the tibia is also in the range of 2 to 3 mm, as advocated by several authors.\(^5\)\(^-\)\(^8\)\(^,\)\(^9\) In none of the specimens, a penetration of more than 5 mm was seen, which minimizes the chance of thermal damage to the bone.\(^10\)\(^-\)\(^14\)

It seems favorable to apply cement to both the tibial surface and the component, when compared with only applying it to the tibial surface. Both techniques produce a sufficient penetration of at least 2 mm; therefore, the clinical relevance needs to be investigated further.

With regard to the femoral cementing technique, no difference in penetration at the distal saw cuts was seen. Both techniques showed a sufficient penetration of \(~3\) mm, suggesting that applying cement to bone surface is as effective as to the component, which contrasts the results by Vaninbroukx et al.\(^23\)

It was remarkable that the cement penetration at the posterior surfaces was very poor. In 14 of the 20 posterior condyles, there was no cement penetration at all. The cement penetration at the posterior condyles is compromised by several factors. It is harder to access for cleaning and applying cement, and the surface is parallel to axis of pressure when placing the knee in full extension during the curing of the cement. An angled cement gun may be the solution.\(^24\)

There was a minor difference in cement distribution at the anterior surface between both techniques. The cement penetration at the anterior surfaces was slightly better than at the posterior surfaces, but still inadequate in most samples. Again this surface is parallel to the axis of pressure when the knee is in extension during the curing of the cement. Applying the cement to the bone, instead of to the component seems to enhance the penetration. The authors of the previous study\(^23\) came to a similar conclusion in their saw bone study. The clinical importance of the poor cement fixation at the anterior and posterior surfaces still remains unclear.

Conclusion

Applying cement to both the tibial bone surface and the tibial component improves the cement penetration, when compared with applying it to the bone surface alone.

On the femoral side, no significant differences were seen between the two techniques. Remarkably, very little cement was seen at the anterior and posterior surfaces.

Conflict of Interest

None.

References
